ORIGINAL SPECIFICATION

"Vehicular Electronic Apparatus Suppressed of Interference in Receiving a Broadcast Wave"

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Vehicular Electronic Apparatus Suppressed of Interference in Receiving a Broadcast Wave

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to vehicular electronic apparatuses, and more particularly to a vehicular electronic apparatus suppressed of interference in receiving a broadcast wave.

2. Description of the Related Art

In the receiver, various noises are to be mixed therein depending upon a state of radio wave propagation, causing disturbance against favorable reception. Particularly, in an FM receiver mounted on a vehicle, there is an increasing possibility of suffering the influence of electromagnetic wave caused by the mounted electronic apparatus as the kind and number of electronic apparatuses mounted on the vehicle increases. Meanwhile, the receiver is susceptible to the noise as caused by the fluctuation in receiving electric field upon vehicle traveling, reflection upon buildings, and so on.

In respect of the EMI (Electro Magnetic Interference) caused by the electromagnetic wave generated by the electronic apparatus mounted on a vehicle, countermeasures are taken to suppress against interference wave radiation by attaching, on the receiver side, a noise suppressing unit, such as a filter or a shield while, on the vehicle-mounted electronic apparatus side, by selecting a CPU for use in the electronic apparatus,

appropriating the printed-board pattern, adding countermeasure parts such as a shield, for example.

As described above, the vehicular electronic apparatus generates various interfering waves (unwanted electromagnetic waves). Particularly, recently there is an increase of vehicular electronic apparatuses mounting microcomputers. This, in turn, increases the case the noise caused by a crystal oscillator or the like for supplying a clock to the microcomputer causes disturbance on the receiving unit of the FM receiver.

In the meanwhile, where a signal is applied to a circuit, such as an amplifier, constituting a receiver, the non-linearity in the amplifier input-output characteristic, if present, causes distortion in its output.

For example, on the vehicular receiver for receiving a broadcast wave of the FM receiver or the like, there are simultaneous arrivals of the other frequency of electromagnetic wave such as the foregoing interference waves, besides a desired frequency of electromagnetic wave. Consequently, a plurality of signals different in frequency are simultaneously applied to the amplifier of a circuit close to the antenna.

In this manner, in case two signals different in frequency are applied simultaneously to the amplifier, the amplifier generates a signal having a new frequency component besides the outputs responsive to the respective frequency components of the two applied signals.

The amplifier response characteristic, when two signals are applied to the amplifier, is called "two-signal characteristic"

to be expressed as in the following.

Now, when assuming t is time, amplifier input is represented as x(t) and output as y.(t) At this time, it is assumed that the amplifier has non-linearity in its input-output characteristic, output y(t) can be approximated as a polynomial of t, as in Equation (1).

$$y(t) = ax(t) + bx(t)^2 + cx(t)^3 + \dots \qquad (1)$$

Subsequently, to this amplifier is added by an input signal {x1(t), x2(t)} represented by Equation (2). Equation (2) expresses two sinusoidal waves different in frequencies (f1 and f2). The amplifier output at this time can be determined by substituting Equation (2) into Equation (1). This result in Equation (3), while Equation (3) is expanded into a result of Equation (4). Incidentally, because there is complexity of coefficients in the expansion, the coefficients are omitted in detailing.

$$\begin{aligned} x(1) &= A \cos(2\pi f1t) \\ x(2) &= B \cos(2\pi f2t) \qquad (2) \end{aligned}$$

$$\begin{aligned} y(t) = &\ a \{A \cos(2\pi f1t) + B \cos(2\pi f2t)\} \\ &+ b \{A \cos(2\pi f1t) + B \cos(2\pi f2t)\}^2 \\ &+ c \{A \cos(2\pi f1t) + B \cos(2\pi f2t)\}^3 \\ &+ \dots \qquad (3) \end{aligned}$$

$$\begin{aligned} y(t) = & \\ & k0 \\ &+ k1 \cos(2\pi f1t) + k2 \cos(2\pi f2t) \\ &+ k3 \cos\{2\pi (2f1) t\} + k4 \cos\{2\pi (2f2) t\} \\ &+ k5 \cos\{2\pi (f1 + f2) t\} + k6 \cos\{2\pi (f2 - f1) t\} \end{aligned}$$

$$+ k7 \cos \{2\pi (3f1) t\} + k8 \cos \{2\pi (3f2) t\}$$
$$+ k9 \cos \{2\pi (2f1 - f2) t + k10 \cos \{2\pi (2f2 - f1) t$$
$$+ k11 \cos \{2\pi (2f1 + f2) t + k12 \cos \{2\pi (2f2 + f1) t \quad (4)$$

Subsequently, the terms of Equation (4) are explained.

The first term is a term having only the coefficient not to change in time. Namely, it signifies that direct current is included in output.

The second term represents an output of basic wave. Namely, it is an output by nature. If it is assumed that the amplifier keeps complete linearity, the coefficient of this term only is finite while the other is zero. In other words, the components other than this term are all newly generated components by the amplifier non-linearity.

The third term has respective second harmonic components of the two input signals. The higher harmonic component is also to be generated when applying a signal singly to the amplifier.

The fourth term is a component of a sum of and difference between two input signal frequencies. By utilizing this component, a heterodyne frequency converter circuit can be configured.

The component of the third and fourth term is to be generated by the secondary coefficient part of Equation (1). Accordingly, in the case to taken out or frequency-convert a second harmonic, the circuit constant is determined such that the relationship of input and output is in a characteristic to be approximated by a secondary function.

The fifth term is a third harmonic component. Meanwhile, the sixth term and seventh term is a component of a sum of and difference between one second harmonic and the other frequency, in which meaning it resembles the fourth term. Incidentally, the fifth, sixth and seventh term is a component to be generated on a tertiary coefficient.

Generally, the frequency component "mf1 ± nf2" (m, n = 1, 2, 3 ...) caused by the non-linearity of a circuit, such as amplifier, is called "intermodulation product".

Now, the two input signal frequencies f1 and f2 assumably has a difference (f1 - f2) of 1 kHz, the component in the rear of the fourth term has a frequency of 1 kHz, e.g. to be heard as a discomfort noise to the FM-broadcast listener.

Incidentally, although coefficient notation was omitted in the foregoing Equation (4), of which coefficients the second term representative of a basic wave component (f1) includes an amplitude value A of one input signal and an amplitude value B (AB^2) of the other input signal B. This means that the amplitude of one signal is influenced by the amplitude of the other signal, which means that changing an amplitude of the other signal causes variation in the amplitude of one signal. This phenomenon is called "cross modulation distortion", which is to be heard as discomfort noise to the listener similarly to the above.

Where an FM broadcast or the like is received by using a vehicular receiver, noise during traveling cannot be heard due to masking by engine sound. However, in the case of reception while halting the vehicle, distortion based, for example, on the

foregoing intermodulation is to be heard as discomfort noise.

As noted before, in respect of these noises, countermeasures are taken to suppress against interference wave radiation by attaching, on the receiver side, a noise suppressing unit, such as a filter or a shield while, on the vehicle-mounted electronic apparatus side, by selecting a CPU for use in the electronic apparatus, appropriating the printed-board pattern, adding countermeasure parts such as a shield, for example.

However, the measure for suppressing the interference wave radiation has low predictability for the effect. In many cases, final decision is impossible without taking measures on each actual vehicle. For this reason, the term required for design or assessment takes long, to increase manufacture cost.

The present invention has been made in view of these problems, and it is an object thereof to provide a vehicular electronic apparatus capable of effectively suppressing the interference with broadcast wave reception resulting from intermodulation.

SUMMARY OF THE INVENTION

The present invention adopts the following means in order to solve the foregoing problem.

A vehicular electronic apparatus comprises: a microcomputer; and a crystal oscillator for determining an operating frequency for the microcomputer; an oscillation frequency of the crystal oscillator being selected such that a frequency difference between a frequency of a broadcast wave

received by a vehicular receiver and an oscillation frequency of the crystal oscillator or a higher harmonic of the oscillation frequency is 15 kHz or higher or 400 Hz or lower, to suppress an interference in receiving the broadcast wave.

In this manner, because of setting an interference wave frequency f2 such that a differential frequency (f1 - f2) is fallen outside an audible frequency band, noise can be suppressed. Meanwhile, with such a method of setting an interference wave frequency, the effect of setting can be predicted with high probability. This eliminates the necessity to conduct an experiment by using an actual vehicle, shortening the term required for design or assessment and enabling efficient development. Furthermore, the noise frequency (f1 - f2) can be previously predicted because it is a difference between a broadcast wave frequency f1 and an interference wave frequency f2 caused from the crystal oscillator or the like, as noted before. Meanwhile, noise intensity (amplitude value) can be predicted from a broadcast wave intensity and interference wave intensity. Accordingly, in case utilizing this fact, it is possible on a particular vehicle to trace an interference wave generation source from the frequency of a noise occurred or to specify a frequency and intensity of occurrence noise on the basis of an existence of a particular interference wave generation source. Due to this, it is possible to carry out noise-suppressing measure on an actual vehicle with greater efficiency.

Meanwhile, a vehicular electronic apparatus comprises: a microcomputer; and a crystal oscillator for determining an

operating frequency for the microcomputer; an oscillation frequency of the crystal oscillator or a higher harmonic of the oscillation frequency is selected falling within a band of an FM-broadcast main signal to be received by a vehicular receiver, to suppress an interference in receiving the FM broadcast wave.

In this manner, because of setting an interference wave frequency f2 within a domain of an FM-broadcast main signal to be received by the vehicular receiver, noise can be suppressed. Meanwhile, with such a method of setting an interference wave frequency, the effect of setting can be predicted with high probability. This eliminates the necessity to conduct an experiment by using an actual vehicle, shortening the term required for design or assessment and enabling efficient development. Furthermore, the noise frequency (f1 - f2) can be previously predicted because it is a difference between a broadcast wave frequency f1 and an interference wave frequency f2 caused from the crystal oscillator or the like, as noted before. Meanwhile, noise intensity (amplitude value) can be predicted from a broadcast wave intensity and interference wave intensity. Accordingly, in case utilizing this fact, it is possible on a particular vehicle to trace an interference wave generation source from the frequency of a noise occurred or to specify a frequency and intensity of occurrence noise on the basis of an existence of a particular interference wave generation source. Due to this, it is possible to carry out noise-suppressing measure on an actual vehicle with greater efficiency.

Meanwhile, a vehicular electronic apparatus having an

electronic unit comprises: a microcomputer; and a crystal oscillator for determining an operating frequency for the microcomputer; an oscillation frequency of the crystal oscillator being selected such that a frequency difference between an FM broadcast receiving frequency of a vehicular receiver and an oscillation frequency of the crystal oscillator or a higher harmonic of the oscillation frequency is 400 Hz or lower, to suppress an interference in receiving the FM broadcast wave.

In this manner, because of setting an interference wave frequency f2 such that a differential frequency (f1 - f2) is fallen outside an audible frequency band, noise can be suppressed. Meanwhile, with such a method of setting an interference wave frequency, the effect of setting can be predicted with high probability. This eliminates the necessity for an experiment to be conducted by using an actual vehicle, shortening the term required for design or assessment and enabling efficient development.

Furthermore, the noise frequency (f1 - f2) can be previously predicted because it is a difference between a broadcast wave frequency f1 and an interference wave frequency f2 caused from the crystal oscillator or the like, as noted before. Meanwhile, noise intensity (amplitude value) can be predicted from a broadcast wave intensity and interference wave intensity. Accordingly, in case utilizing this fact, it is possible on a particular vehicle to trace an interference wave generation source from the frequency of a noise occurred or to specify a frequency and intensity of occurrence noise on the basis of an

existence of a particular interference wave generation source. Due to this, it is possible to carry out noise-suppressing measure on an actual vehicle with greater efficiency.

Meanwhile, a vehicular electronic apparatus having an electronic unit comprises: a microcomputer; and a crystal oscillator for determining an operating frequency for the microcomputer; a receiving frequency of a vehicular receiver and an oscillation frequency of the crystal oscillator or a higher harmonic of the oscillation frequency are selected coincident in frequency, to suppress an interference in receiving the broadcast wave.

In this manner, because of setting an interference wave frequency f2 such that a differential frequency (f1 - f2) is "0", noise can be suppressed. Meanwhile, with such a method of setting an interference wave frequency, the effect of setting can be predicted with high probability. This eliminates the necessity for an experiment to be conducted by using an actual vehicle, shortening the term required for design or assessment and enabling efficient development.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a figure explaining a vehicular electronic apparatus according to an embodiment of the present invention;

Fig. 2 is a figure showing a frequency-temperature characteristic of a crystal oscillator;

Fig. 3 is a figure explaining an oscillation circuit using a crystal oscillator;

Fig. 4 is a figure showing a relationship between an FM-broadcast wave frequency and an interference wave frequency;

Fig. 5 is a figure showing a relationship between a modulation frequency and a sound level; and

Fig. 6 is a figure explaining a noise improving ratio.

DETAILED DESCRIPTION OF THE INVENTION

Now, an embodiment of the present invention is explained with reference to the attached drawings. Fig. 1 is a figure illustrating a vehicular electronic apparatus according to an embodiment of the invention. In the figure, 1 is a vehicle body, 2 is a broadcast wave, and 3 is an antenna attached on the vehicle body. 4 is an amplifier configuring an FM receiver and the like, wherein the amplifier 4 has non-linearity in its input-output characteristic. 5 is a speaker of the receiver, while 6 is a vehicular electronic apparatus such as a vehicle-mounted stereo player or car navigator system. The vehicular electronic apparatus 6 is configured by a microcomputer and the like. The microcomputer has a crystal oscillator 7 to generate a clock needed for the operation.

Now, the vehicular electronic apparatus mounted on the vehicle body 1 is set in an operating state. In this state, the FM receiver is powered on to start receiving a broadcast wave at a predetermined frequency f1, for example. At this time, the crystal oscillator provided by the microcomputer of the vehicular electronic apparatus 6 oscillates at a predetermined frequency, to radiate an electromagnetic wave (interference wave) at a

frequency f2 as an oscillation frequency or a higher harmonic thereof.

The broadcast wave at the frequency f1 is inputted to the amplifier 4 configuring the FM receiver, through the antenna 3. Meanwhile, the interference wave at the frequency f2 generated by the vehicular electronic apparatus 6 is inputted to the amplifier 4 through the antenna 3 or directly.

Namely, two signals different in frequency (broadcast wave at a frequency f1 and interference wave at a frequency f2) are simultaneously applied to the amplifier 4. The amplifier 4 generates a new frequency of signal besides the outputs with respect to the frequencies of the two applied signals, as described before. Of the new frequencies of signals generated herein, the frequency component greatly different from the frequencies f1 and f2 can be removed by the filter or the like provided on the circuit.

Meanwhile, there arises a case that a differential frequency (f1 - f2) of the newly generated signal frequencies enters an audible range, causing a case it is not to be easily removed by the filter. In such a case, the frequency f2 is favorably set to shift the differential frequency out of the audible range. In the below, setting the frequency f2 is explained. Incidentally, according to an experiment by the inventors, it has been revealed that, in the case of considering a slight noise as caused from the vehicle-mounted FM receiver or the like, the human's audible range lies, approximately, 400 Hz to 15 kHz (sound (noise) at the outside of the frequency band is

extremely difficult to hear).

Fig. 2 is a figure showing a frequency-temperature characteristic of the usual crystal oscillator (AT-cut). The AT-cut crystal oscillator is broadly used because of less frequency change against the temperature change at around the normal temperature. As shown in the figure, the usual crystal oscillator has a frequency change of approximately 100 ppm to 5 ppm where the temperature change range thereof is -40°C to +85°C.

Fig. 3 is a diagram explaining an oscillator circuit using a crystal oscillator 7. Fig. 3A is a figure showing a standard basic wave oscillator circuit, and Fig. 3B is a figure showing a load-capacitance characteristic of the crystal oscillator 7 in the oscillator circuit.

As shown in Fig. 3B, adjusting the capacitance of a variable trimmer capacitor Cv makes it possible to adjust a load capacitance Cl. This can adjust oscillation frequency. For this reason, oscillation frequency can be adjusted to a predetermined value irrespectively of the manufacturing error of the crystal oscillator, variation in the element configuring the oscillator circuit and so on.

However, in the case, for example, of a crystal oscillator having an oscillation frequency of crystal oscillator (including a higher harmonic of the oscillation frequency) to cause an interference wave of 80 MHz, when the oscillation frequency varies 100 ppm due to temperature change, the frequency of interference wave varies 8 kHz. Accordingly, in this case, even in case the oscillation frequency is made coincident with the broadcast wave

frequency f1, the differential frequency (f1 - f2) is within an audible range due to the temperature change. Namely, noise is to be heard.

Accordingly, in order for the noise not to be heard regardless of temperature change, the oscillation frequency change due to temperature change must be equal to or less than 5 ppm. In this case, the differential frequency (f1 - f2) is 400 Hz or lower, being not fallen within the audible range. Incidentally, it is easy to obtain, in the market, a crystal oscillator having an oscillation frequency change based on temperature change is 5 ppm or lower.

Meanwhile, in place of the technique to set the differential frequency (f1 - f2) at 400 Hz or lower, the differential frequency (f1 - f2) can be set at 15 kHz or higher. In this case, the oscillation frequency is satisfactorily part distant from the reception frequency f1.

Fig. 4 is a figure showing a relationship between a frequency f1 of FM broadcast wave and a frequency f2 of interference wave. As shown in the figure, the FM broadcast frequency f1 comprises an FM carrier signal f0, a pilot signal fp1, a second harmonic signal fp2 of the pilot signal, a third harmonic signal fp3 of the pilot signal .... The differential frequency between these signals and the interference wave frequency f2 results in a noise frequency. Incidentally, the frequency difference between the usual FM-broadcast FM carrier signal f0 and the pilot signal fp1 is 19 kHz as shown in the figure, while the frequency difference between the higher harmonics (fp2,

fp3) of the pilot signals is 19 kHz.

Fig. 4A shows an example that an interference wave is supplied such that the frequency f2 thereof has a frequency difference 50 kHz (deviation between signal centers of 50 kHz) with respect to the FM carrier signal f0. In this case, the interference wave frequency f2 and the higher harmonic fp2 of pilot signal have a frequency difference of 12 kHz, while the interference wave frequency f2 and the pilot signal fp3 have a frequency difference of 7 kHz (shown at 12/7 in the figure).

Fig. 4B shows an example that an interference wave is supplied such that the frequency f2 thereof has a frequency difference 40 kHz (deviation between signal centers of 40 kHz) with respect to the FM carrier signal f0. In this case, the interference wave frequency f2 and the higher harmonic fp2 of pilot signal have a frequency difference of 2 kHz, while the interference wave f2 and the higher harmonic fp3 of pilot signal have a frequency difference of 17 kHz (shown at 2/17 in the figure).

In the below, similarly the deviation between signal centers are taken 30 kHz, 20 kHz, 10 kHz and 0 kHz, which examples are shown in Figs. 4C, 4D, 4E and 4F.

In this manner, generated is a noise having various frequency components based on a frequency difference between an FM broadcast wave frequency f1 and an interference wave frequency f2. Accordingly, the interference wave frequency f2 must be set such that these frequency components are fallen outside the audible frequency band, as shown for example in Fig. 4F. Incidentally, because the FM broadcast wave frequency f1 is known

in each locality, it is easy to set the interference wave frequency f2 such that the noise frequency component is fallen outside the audible frequency band.

Incidentally, in the case to set the differential frequency (f1 - f2) at "0" as shown in Fig. 4F, the noise based on the differential frequency (f1 - f2) can be not heard by the human.

Incidentally, in case the interference wave is at a clock frequency for use on a microcomputer, the differential frequency (f1 - f2) can be rendered "0" by placing the clock frequency synchronous with a reception frequency. In this case, by using for example an accurate crystal oscillator or by using means for frequency-dividing a pulse synchronized with a broadcast frequency generated by a PLL circuit used in a receiver tuner, it is possible to obtain a clock frequency synchronized with or nearly synchronized with the reception frequency.

Next, Fig. 5 is a figure showing an example on a relationship between a modulation frequency (base-band frequency) and a sound level (noise level within a vehicle), in a broadcast signal in a carrier wave suppressed AM-FM scheme a stereo sub-carrier wave is suppressed (wherein the relationship between a modulation frequency and a sound level shows a different characteristic on each vehicle). The curves in the figure are curves connecting between points having the same amplitude value of noise signal.

As shown in the figure, it is to be understood that noise level is suppressed in a low band region of an FM modulation part as an addition signal added with left and right sound signals. Also, comparing between the noise levels of the FM modulation part

and AM modulation part, it can be seen that the FM modulation part is lower in noise level and more advantageous.

Fig. 6 is a figure explaining a noise improving ratio with respect to a continuous noise in amplitude modulation and frequency modulation. Fig. 6A is a figure showing a noise spectrum in amplitude modulation (AM) and frequency modulation (FM), while Fig. 6B is a figure showing an FM stereo signal (base-band signal).

As shown in Fig. 6A, the noise spectrum in amplitude modulation is constant at any of modulation signal frequencies. Meanwhile, the noise spectrum in frequency modulation has a characteristic that noise intensity increases in proportion to modulation signal frequency, because of a modulator characteristic (triangular noise spectrum).

Because the components of the continuous noise are not the same in phase, provided that the noise voltage at each frequency is e, the noise amount per frequency in the case of amplitude modulation is N and the maximum frequency of a transmission signal is f_{max}, the noise amount may be determined by integrating e^2 from frequency 0 to f_{max} and determining a square root thereof. The noise amount N_{AM} in the case of amplitude modulation is given by

$$N_{AM} = N\ (f_{max})^{1/2}.$$

Meanwhile, provided that the frequency transition in frequency modulation is f_d, the noise amount N_{FM} in frequency modulation is given by

$$N_{FM} = N\ (f_{max})^{3/2}\ /\ \sqrt{3}\ f_d.$$

Accordingly, the noise improving ratio N_{FM}/N_{AM} in continuous

noise, provided that deviation ratio m is f_d/f_{max}, is given by

$$N_{FM}/N_{AM} = 1 / \sqrt{3}\ m.$$

Herein, in case the deviation ratio m is assumed 5, then $N_{FM}/N_{AM} = 1 / \sqrt{3} \times 5 = 1 / 8.66$ results.

In case this is applied to the broadcast signal in the carrier wave suppressed AM-FM scheme shown in Fig. 6B, shown is a fact that the main signal (L + R) in frequency modulation is improved in S/N ratio by 8.66 times relative to the sub signal (L - R) in amplitude modulation.

If the above is summarized, it can be seen that the interference wave frequency f2 as a noise frequency against the FM receiver is desirably fallen within a domain of an FM broadcast main signal.

In the above explanation, it was explained that noise can be suppressed by (1) setting an interference wave frequency f2 such that the differential frequency (f1 - f2) is fallen outside an audible frequency band, (2) setting an interference wave frequency f2 such that the differential frequency (f1 - f2) is at "0", (3) setting an interference wave frequency f2 within a domain of an FM broadcast main signal the vehicle-mounted receiver is to receive.

With the method of setting an interference wave frequency as in the above, the effect of setting can be predicted with high probability. This eliminates the necessity to conduct an experiment by using an actual vehicle, shortening the term required for design or assessment and enabling efficient development.

In the meanwhile, the noise frequency (f1 - f2) can be previously predicted because it is a difference between a broadcast wave frequency f1 and an interference wave frequency f2 caused from the crystal oscillator or the like, as noted before. Meanwhile, noise intensity (amplitude value) can be predicted from a broadcast wave intensity and interference wave intensity.

Accordingly, in case utilizing this fact, it is possible on a particular vehicle to trace an interference wave generation source from the frequency of a noise occurred or to specify a frequency and intensity of occurrence noise on the basis of an existence of a particular interference wave generation source. Due to this, it is possible to carry out noise-suppressing measure on an actual vehicle with greater efficiency.

As explained above, according to the present invention, a vehicular electronic apparatus can be provided which can suppress interference against broadcast wave reception as caused by mutual modulation.